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S P E C I F I C A T I O N

Docket No. 00-C-015

DRAFTED - SPECIFICATION - DRAFTED

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, Anthony M. Chiu, a citizen of the United States of America residing in the State of Texas, have invented new and useful improvements in a

**SURFACE MOUNT PACKAGE FOR LINEAR ARRAY SENSORS**

of which the following is a specification:

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention:

5 The present invention relates in general to packaging and mounting semiconductor devices and in particular to packaging and mounting semiconductor photo transmitter/receiver (transceiver) devices in linear arrays. Still more particularly, the present invention relates to packaging semiconductor devices in a linear array of photosensors having a total length much greater than the size of a substrate on which the devices are formed.

### 2. Description of the Prior Art:

15 The prevalence of imaging systems in contemporary consumer electronics relies in large measure on the fabrication of photosensors composed of charge coupled devices and CMOS devices. The charge coupled devices serve as photo-sensitive elements, with photons (light) impacting the surface of the charge coupled device creating charge at the terminals of the device. While a single sensing element detects light only at a single point, an array of sensing elements can detect variations of light reflected off an object being imaged as a function of position in a line or plane, enabling 25 electronic encoding of a digital image of the object. Arrays of charge coupled devices find wide use in electronic products ranging from digital cameras to telecopier (facsimile or "fax") machines.

30 In some products, a linear array of photosensors detects a narrow line (often one or two pixels wide) of light reflected from the object being imaged. Moving the sensors

relative to the object and/or the object relative to the  
sensors by the width of the array creates an adjacent linear  
image, a process which may be repeated with the adjacent  
5 linear images (also called optical lines) combined to form a  
two-dimensional image. In the case of flat-bed scanners, the  
sensor array typically moves relative to the scanned page to  
capture the image, while fax machines generally move the paper  
across the sensors. Use of a linear array to capture two-  
10 dimensional images reduces system cost since fewer sensor  
units are required.

15 Linear arrays of photosensors are typically manufactured  
from strips of integrated circuits containing charge coupled  
devices and mounted on printed circuit boards. Currently, the  
integrated circuits are mounted in an unencapsulated silicon  
form, then connected to a power supply and other support  
electronics mounted on the printed circuit board through the  
use of gold bond wires. The bond wires are then protected  
utilizing liquid encapsulation or silicon gel. This  
20 technique, often referred to as "Chip On Board" technology,  
provides ease of manufacture in production of sensor arrays  
having charge coupled devices as well as other integrated  
circuit designs.

25 However, Chip On Board technology causes removal and  
replacement of a defective integrated circuit segment from a  
linear array to be prohibitively difficult. Simple removal of  
an integrated circuit segment from a linear array for  
replacement is simply not possible in an economical manner.  
30 An array containing a defective segment must therefore simply  
be discarded. As the length of linear arrays increases, and  
the array includes more integrated circuit segments, the  
likelihood of at least one segment being or becoming defective  
increases substantially. Therefore, maintaining an acceptable

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yield in the linear array production constrains the length of arrays, a problematic limitation in that the number of parts and manufacturing steps in producing devices utilizing the linear arrays is increased. The limitation on array length also requires use of multiple linear arrays where designers would prefer a single linear array of greater length. Furthermore, multiple arrays must be aligned relative to each other during assembly.

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It would be desirable, therefore, to produce linear arrays with greater length and more easily replaceable integrated circuit segments.

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## SUMMARY OF THE INVENTION

In linear arrays of charge coupled device photosensors, the sensor integrated circuits are contained in surface mountable packaging allowing individual segments to be soldered into place within the array. For solder-mountable packaging, unencapsulated sensor circuits are mounted onto a lead frame strip with the space between the circuits equaling the width of a singulation saw. After die mounting and wire bonding, a continuous strip of plastic or resin molding covers the wire bonds on one side and the edge of the silicon on the other, protecting the lead frame strip and other parts, leaving the active sensor area exposed. The lead frame is then trimmed and formed in a conventional manner, and the packaged sensor circuits are separated with a singulation saw cutting between the circuits. The resulting self-contained device may then be mounted within a linear array with solder rather than depending on Chip On Board technology. Leads are preferably soldered to the board on only one side, with the other side floating freely over the appropriate contacts for ease of mechanical adjustment. Individual sensor segments within the array may be readily removed and replaced in the event of a defect.

## BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, and further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

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**Figure 1** depicts a pair of integrated circuit devices mounted on a lead frame strip, prior to completion of packaging, in accordance with the preferred embodiment of the present invention;

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**Figure 2** is a cross-sectional view of a mold and lead frame strip employed in packaging sensor circuits in accordance with a preferred embodiment of the present invention;

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**Figures 3A-3B** depict plan and cross-sectional views of a packaged sensor device in accordance with the preferred embodiment of the present invention; and

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**Figure 4** is a plan view of several completed and packaged integrated circuit sensor devices mounted on a printed circuit board to form a linear sensor array in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION

The following description details the structure, application and features of the present invention, but it will be understood by those of skill in the art that the scope of the invention is defined only by the issued claims, and not by any description herein. The process steps and structures described below do not form a complete process flow for manufacturing integrated circuit packages. The present invention can be practiced in conjunction with integrated circuit package fabrication techniques currently used in the art, and only so much of the commonly practiced process steps are included as are necessary for an understanding of the present invention. The figures showing portions of an integrated circuit package during fabrication are not necessarily drawn to scale, but instead are drawn so as to illustrate the important features of the invention.

With reference now to the figures, and in particular with reference to **Figure 1**, a lead frame strip on which integrated circuit sensor devices are mounted, prior to completion of packaging in accordance with the preferred embodiment of the present invention, is depicted. In the figure, the integrated circuit sensor device die **104a-104b** are mounted on a metal alloy (typically either iron-nickel or copper based) lead frame strip **102** aligned collinearly along a centerline **106**, and contain conventional sensor devices for detecting variations in ambient light. The two integrated circuit sensor segments **104a-104b** are separated by a space **108** approximately equal to the kerf width of a singulation saw, about 50 microns. Charge coupled devices or other photosensitive devices are formed in a line along the length of the integrated circuit segments **104a-104b** up to the edges

of the respective die adjoining space 108. Additional sensor device die (not shown) may be similarly mounted on the remaining portion of the lead frame strip 102.

5 As in the conventional art, lead frame strip 102 may be formed by stamping and masked etching, and includes a plurality of lead frames each having centrally located supports 110a, 110b to which the integrated circuit die will later attach (commonly referred to as a "die paddle") and a network of leads 112. Die paddles 110a and 110b are shorter in length than the integrated circuit die which will be mounted on the lead frames within lead frame strip 102, so that spacing between adjacent integrated circuit die is limited by the length of the die. Metal strips (dam bars) 114, located between the leads at points which will eventually lie just outside the edge of the completed molded packages, prevent molten encapsulant which seeps from the mold fixture from flowing out onto the leads and later adversely affecting lead trim and form operations. Additional bars (shorting bars) 116, located between the lead tips, provide protection of the leads from mechanical damage during processing and handling. Generally a number of lead frames are temporarily connected together via larger shorting strips (bars) 118 to facilitate automated processing. Alignment or "tooling" holes 120 in the lead frame strip 102 allow for automated handling, attachment of the remaining parts of the circuit to the lead frame, and encapsulation of the mounted die 104a-104b.

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Integrated circuit die 104a-104b are affixed to the die paddles 110a-110b of the lead frame utilizing an adhesive, such as polymers (including resin-based epoxies and

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polymides), solder, or gold eutectic. Integrated circuit die 104a-104b are mounted with a separation approximately equal to a kerf width of a singulation saw which will be used to separate packaged integrated circuits. Once each integrated circuit die 104a-104b is affixed to the lead frame strip 102, wire bonding will typically create connections between bond pads on the integrated circuit surface and leads 112 providing electrical connection to outside electronic parts. Small gold wires are welded or soldered (usually thermosonic gold wirebonding) between bond pads and selected leads 112 to create "pins" for the completed, packaged circuit.

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Referring to **Figure 2**, a cross-sectional view of a mold and lead frame strip employed in packaging sensor circuits in accordance with a preferred embodiment of the present invention is illustrated. The figure illustrates a cross-section of lead frame strip 102 depicted in **Figure 1** taken at section lines A-A and of a mold when the lead frame strip 102 is mounted to the mold 200 for encapsulation of the integrated circuit die 104a. When lead frame strip 102 with integrated circuit die 104a is mounted to mold 200, a portion 202 of the mold 200, about 100-200  $\mu\text{m}$  in width, abuts the surface of integrated circuit die 104a on which the photosensitive devices are formed, preventing the encapsulating material from forming on that portion of the integrated circuit die surface and leaving that portion exposed. In general, this part of the mold that is in contact with the silicon chip surface is made from soft material such as silicone rubber or cushioned by a polyimide film. Portion 202 of mold 200 extends to an edge of the integrated circuit die 104a, and a sloped surface of mold 200 provides a mold cavity region in which wire bonds

may be encapsulated. The cavity includes several similar regions for receiving each integrated circuit die and attached bond wires which are affixed to the lead frame strip. Mold 200 also includes tooling pins 204 projecting from a surface 5 adjacent the mold cavity region and received by tooling or alignment holes 120 within the lead frame strip 102.

Lead frame strip 102 and integrated circuit die 104a are then molded with a thermosetting resin or thermoplastic 10 injected into the open spaces of mold 200, covering a portion of the lead frame 102 and the integrated circuit die 104a except for the surface abutting mold portion 202. The plastic or resin will also cover bond wires and will adhere to the surfaces of all of the parts exposed to the resin, further securing the integrated circuit to the lead frame. The sensor portion on which the charge coupled devices which actually receive the photon are formed, however, will remain uncovered, allowing light from the object being imaged to reach the photosensors. Various encapsulation processes (including transfer molding, injection molding, and reaction-injection molding) may be employed.

After the formation of the epoxy or plastic covering using mold 200, the lead frame strip 102 trim and form 25 operations commence to create connections easily available in mounting the integrated circuit device to other pieces of electronic equipment. Singulation is performed by sawing through the packaging and lead frame strip between the integrated circuit die 104a and 104b within the gap 108 left 30 for that purpose.

With reference now to **Figures 3A and 3B**, plan and cross-

sectional views of a packaged sensor device in accordance with the preferred embodiment of the present invention are depicted. The packaged device contains the integrated circuit sensor device with a sensor region 302 exposed, not covered by the packaging plastic or resin 304 which otherwise encapsulates the integrated circuit die, the portion of the lead frame to which the sensor die is affixed, and the bond wires and adhesive connecting the sensor die to the lead frame.

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The packaged integrated circuit also includes leads 306 on one side and leads 308 on the other. In the assembled linear array, one set of leads 306 is preferably soldered into place while the other set 308 floats freely over the contacts to provide ease of mechanical adjustment in the finished array. Solder around the soldered leads 306 may be reflowed to allow removal of defective finished packages from the array.

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Referring to **Figure 4**, a plan view of several completed and packaged integrated circuit sensor devices mounted on a printed circuit board to form a linear sensor array in accordance with a preferred embodiment of the present invention is illustrated. A printed circuit board 400 is shown on which several completed circuit packages 402a-402h are mounted, with the exposed region of each package aligned. Errors in alignment may be offset by control circuitry or software compensation. As noted above, preferably leads on one side of each package 402a-402h are soldered while leads on the other side remain in floating contact with conductive structures on the printed circuit board 400. Alignment may be

adjusted by "floating" the soldered leads. The minimum possible space between each pair of adjacent packages 402a-402b, 402b-402c, 402c-402d, 402d-402e, 402e-402f, 402f-402g, and 402g-402h within the linear array is maintained, 5 preferably with adjacent packages in contact with each other if possible so that less than one pixel width of dead space is created between discrete linear array packages. Even with automated mounting of packages 402a-402h on circuit board 400, spacing of less than 10 microns between adjacent packages 10 should be possible, and image correction and extrapolation algorithms may be employed to derive image data for portions of optical lines which are not directly imaged due to such spacing. A 10  $\mu\text{m}$  pixel is equivalent to 2540 dpi (dots per inch). For fax machines and other coarse scanning devices, such spacing is adequate to provide satisfactory imaging resolution. Alternatively, two lines of staggered packages 15 may be mounted on the circuit board 400 to obtain greater resolution.

The present invention allows individually packaged integrated circuit sensor segments within a linear array to be easily removed by soldering the segments into place on the circuit board rather than affixing the sensor segments to the board with a silicon gel or liquid encapsulation coating. 25 Replacement of a single segment after discovery of a defect is thus enabled. Since the cost of replacing a single integrated circuit package is far less than the cost of discarding an entire linear array containing a single defective sensor segment, the present invention should allow for the 30 construction of far longer linear arrays, and high resolution arrays of multiple rows.

While the invention has been particularly shown and

described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

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